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Estimating potential saving with energy consumption behaviour model in higher education institutions

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ABSTRACT

Towards sustainable Higher Education Institutions (HEIs), energy consumption behaviour is one of several issues that require an attention by facilities manager. Information from the behavioural aspect would be useful for facilities manager on managing the energy and determining potential energy saving. A lack of information negatively affects this aim. Hence, this paper proposes a methodology for assessing the energy consumption behaviour with the objective determining potential energy saving. The method used energy culture framework as basis and joined with centrographic approach and multiple-regression analysis. A self-administrated survey carried out involving 1400 respondents in selected HEIs. There are four types of energy use among students in HEIs namely, 'high', 'low', 'medium' and 'conserve' determined from the centrographic analysis. The energy consumption behaviour model was developed and tested against the holdout sample. Through the model's application, there is a vast potential for energy savings with over 55 kWh daily among the students.

1. Introduction

In facilities management (FM), energy must be managed properly without wasting organizational resources [1]. An increase of energy usage and lifestyle factors among students in Higher Education Institutions (HEIs) are the main factors for assessment of energy consumption behaviour patterns [2,3]. This is to ensure that the university budget for energy is not exceeded and to create a benchmark of energy use. However, there is a lack of knowledge and systematic approaches of assessing energy consumption behaviour pattern among HEIs.

This paper proposes a methodology of "energy culture" framework. The concept was analysed using centrographic approach through standard deviation ellipse (SDE) calculation and multiple-regression analysis (MRA). Hence, the three main objectives in this paper were set. First was determining an energy consumption pattern, second was developing an energy consumption behaviour model (ECBM), and finally determining the potential energy saving among Malaysian HEIs students.

2. Literature review

Energy must be defined in terms of the ways in which it manifests itself [4]. It is variously classified as heat, light, sound, radio, radar, TV, electricity, magnetism, mechanical energy, growth, and even "matter". It has been difficult for the layman to accept that this range represents different manifestations of the same thing. Hence, to do justice to the concept of energy, it requires treating each of its manifestations as it is treated by experts in that particular field.

Energy consumption behaviour can be defined as the total energy use of the occupant from both human and physical characteristics. The statement is consistent with previous studies which state:

> "*Buildings per se do not consume energy; rather people living and working in building use energy*" — Stafford [5]

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"*Human attitudes, income and intentions do not directly consume electricity. Rather they influence how the physical devices are operated*" – Cramer et al. [6]

These early statements strongly agree that user behaviour is the key in explaining energy consumption. It has to combine the physical elements (e.g., the building's characteristics, appliances, etc.) and the human variables (e.g., beliefs, demographic, lifestyle, etc.) in order to measure the energy consumption behaviour. Other researchers also view energy consumption behaviour as demand which serves to explain the needs and preferences of individuals in terms of their energy use [7–10].

It further needs to explain energy consumption behaviour. Although it has been studied since 70s, when the popularity of the topic was rising, many unexplained elements still exist. Lately, the trend in energy studies has shifted towards a conservation focus. A high level of awareness among researchers regarding global warming problem means that energy consumption behaviour research is again taking place, where an assessment of the micro aspects of behaviour is required in order to develop strategic policy and programs for reducing energy demand. However, as reported in the literature, model development was found to be lacking, especially in terms of determining exact figures, which are not provided by the conceptual model which is generally used in relation to this topic.

2.1. Lifestyle

People's lifestyle affects energy consumption in a significant way, due to both cultural and social variables [10]. 'Lifestyle' is originally a sociological term that has developed many meanings. Lifestyle is defined as "distinctive modes of existence that are accomplished by persons and groups through socially sanctioned and culturally intelligible pattern of action" [11,12]. The concept is famous in marketing studies and has long been used in consumer research and advertising. In energy research, it refers to the combination of culture, social class, consumer choices, behaviour, historical trends, and marketing that determine energy end-use [12]. The relevance of lifestyle to energy consumption is illustrated by findings that similarly structured households with identical physical shells are associated with widely varying energy usage [11].

Lifestyle is usually conceptualized as a consumption pattern influenced by decisions at various points across the lifespan, such as what profession to engage in, where to live, when (or whether) to marry and have kids, and more proximal choices regarding what types of electrical appliances to buy, and how and when to consume the energy [13,14]. Thus, this concept suggests that analysis of lifestyle and energy consumption needs to encompass not only the traditional demographic segmentation elements, but also the information about types of appliances the individual owns and how they use them [12]. Furthermore, through understanding lifestyles, better public policy can be designed in relation to energy [15].

2.2. Energy culture framework

The energy aspect of lifestyle has generated much attention from researchers. One of the intentions is the greater number of research of the integrating models. Aims of the integrating models are to seek the driver of behaviour, and show relationship between drivers. Early studies can be found examined household energy use in term of their energy behaviour [8]. The aims were to model the energy use from the residence towards energy conservation. These include their socio-demographic factors, family life-style; energy prices; energy related behaviour; cost benefit trade-offs; effectiveness and responsibility; feedback; information and home characteristic discussed in term of ventilation and temperature perspective.

The impetus for this research came from the idea of an 'Energy Culture', first introduced for household energy consumption [16]. The cultural model was based on four dimensions of energy consumption: engineering, economic, psychology and anthropology.

Energy culture as drawn by previous researcher is only a concept [16]. Other researcher draws on a wide range of literature on energy behaviour and attempts to use a system perspective [17]. While the approach acknowledges an important sociological influence from practice theory, it also has strong links to lifestyle research in marketing and the first that attempts to realize the idea of energy culture empirically [17].

"Culture" here refers to the diversity of values, beliefs, knowledge, practice, technology and other cultural determinants that exist within any given society [17]. The 'Energy Cultures' approach developed has some interesting parallels to all these approaches [17]. Different integrated patterns of behaviour – similar to 'lifestyles' – should be identifiable based on the differences in material culture, cognitive norms and everyday practices. In this approach, behaviour is seen as an amalgam of those three principal components which interact together to produce a self-reinforcing system that are characterized by strong habits.

It has been argued that there is no single analytical approach in the previous studies that provides a framework for analysing more than a small portion of behaviour, or providing reliably successful interventions [17]. The analysis overlooks the importance of influences beyond the consumer, which includes "producers, vendors, installers, regulators, financiers, a long-lived built environment and technology stock, and a range of ideas and motivations" [18]. Thus, the aims of the Energy Cultures framework is to centre on the behaviour of individuals within the system, to explore outwards from the aspects of the system that most strongly influence behaviour, and from there to consider what interventions might be successful in achieving behavioural change.

The framework in Fig. 1 suggests that consumer energy behaviour can be understood at its fundamental level by examining the interactions between cognitive norms, material culture and energy practice [17].

In this paper, the framework designed was used as a basis to assess energy consumption behaviour among Malaysian HEI students. Previous research only focuses on demographics from a cognitive-norm aspect, a device and setting in material aspect and household activity in energy practice. This paper proposes an expansion of the "energy culture" framework for assessing energy consumption behaviour among Malaysian HEI students. The variables include environmental concern, social aspiration, comfort and education for cognitive norm aspect, device and building regulations from material aspect, and finally activities and social marketing of energy practice aspect (see Fig. 1).

2.3. Centrographic approach

The concept of the centrographic approach is used in this paper to assess energy consumption patterns. It is usually applied in geographical and mathematic fields. It comprises a set of measures and indices for thread cription and analysis (point areas located in a spatial system), equivalent to similar measures and indices in other branches of statistics dealing with non-geographic sets of data [19]. The centrographic's unique approach is that it represents a multi-dimensional structure presented in the simplest form as a map and location information

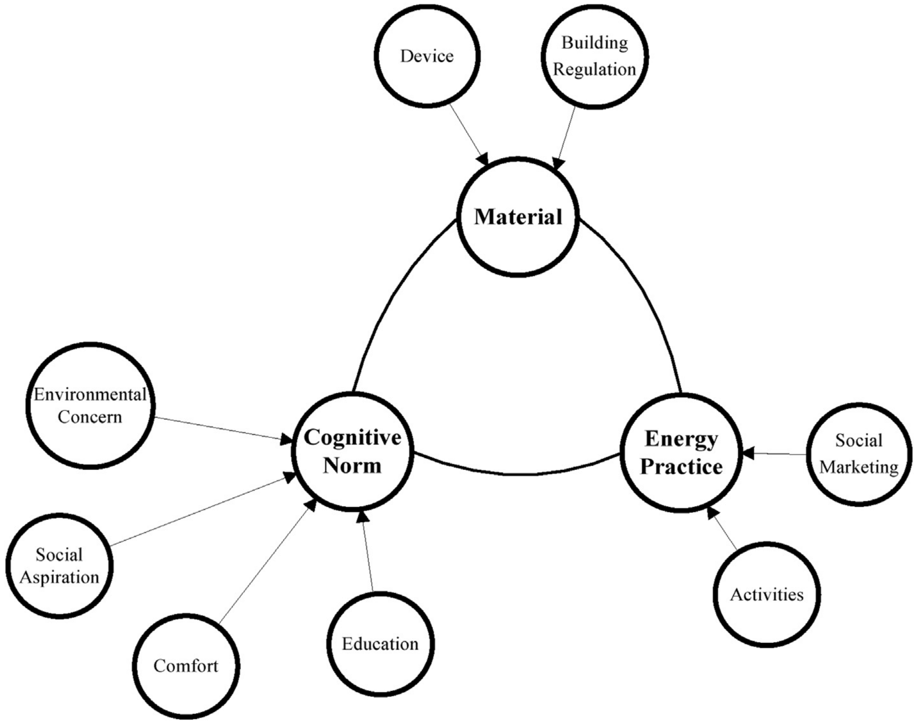

Fig. 1. Selected factors of “energy culture” framework.

(latitude and longitude: x, y). Basic univariate statistics such as mode, mean and median, variance, and standard deviation are encapsulated in the method. The main benefit of the centrographic model is its ability to measure the centrality of a population using a SDE. An SDE allows a user to generalize fairly objective terms about the spatial properties of a particular point of distribution. This may be at different weightages or where the number of points is large enough to prelude a summary or generalisation by visual inspection [20,21].

This approach has potential to be explored in behavioural studies [19]. However, combination of the approach with behavioural aspects is rarely found in the literature. Research topics that utilize the centrographic approach include geography [20], geographical profiling on crime [20,21], residential segregation [22,23] and natural mineral deposits [24]. The approach is not limited to presenting the data in terms of mapping, but also has the capability to segregate the data into different levels of pattern, and to visualise the centre point from the cumulative data. In this paper, this approach was used to determine energy consumption pattern among Malaysian HEIs student through the segregation of the SDE calculation. Segregation will show accurate measurements of the boundaries for each pattern in exact figures.

In order to conduct an assessment of energy consumption behaviour using the concept highlighted, a mathematical model of energy consumption behaviour was proposed. From energy consumption behaviour, the process of energy was used, e.g., behavioural model of residential energy use [9], theoretical framework of macro-micro energy consumption behaviour [8], integrated descriptive framework for energy use and behaviour based on system theory [7], ‘multigenic’ model on energy consumption [10] and the ‘multi-factorial model’ [25]. The advantage of developing a mathematical model is that the results are present in exact figures rather than in a conceptual format. This mathematical model approach is important for an FM manager, who needs exact figures for managing organizational resources.

3. Methodologies

Two main stages of methodology are highlighted in this paper. The first stage was data collection for the study, and the second stage focused on determining the energy consumption level, developing the energy consumption behaviour model, determining the energy consumption pattern, and finally analysing the holdout sample for potential energy saving.

During stage one, the data were collected through a survey involved 1358 students of four selected universities in Malaysia. Questionnaires were used to elicit the information regarding their energy consumption. The questionnaire was designed in three sections. In the first part, data were collected about respondent demographics. The second part examined building regulations, environmental concerns, social aspirations, comfort, education, and social marketing factors. This study chose to use 'continuous rating scale/graphic rating scale' as an instrument for assessing energy consumption behaviour patterns (scaling from 0 = unacceptable to 100 = totally acceptable). The final sections of the questionnaire were intended to determine respondent's energy consumption, which included device and activities factors. It is a list of electricity appliance generally used by the respondents. It includes personal appliances (such as TVs, computers, and others), lights and air conditioning. The objective of this section was to measure the respondents' energy consumption in kWh unit before conducting the analysis.

Building regulations refer to energy regulation in the student accommodation (hostel), and device to any electrical device used by the students in the hostel. From the energy practices aspect, activities refer to normal activities in the hostel including personal studies, sleeping, cooking and so on. Social marketing refers to level of acceptance of the energy conservation program, buying energy efficiency products and so on. Environmental concerns refer to concerns about nature and biodiversity, aesthetic beauty, and environmental quality. Social aspiration refers to beliefs, values, and habits. Comfort refers to changing fan setting, allowed natural air in the room, etc. Finally, education refers to acceptability on the energy consumption knowledge. This research measured the social/indirect factors of energy consumption behaviour with a continuous rating scale. Direct factors such as activities and device use were measured in kWh. The measurement was selected based on its effectiveness in previous studies (see Table 1).

In stage two, to determine energy consumption level, calculations were made using basic energy consumption formula. Calculated energy consumption (observe energy consumption) were plotted in graph based on the total duration and kWh. Next was determination of energy consumption behaviour pattern using a centrographic approach through SDE calculation. The calculations should reveal patterns of energy consumption and normal energy consumption. The analysis continued for developing the energy consumption behaviour model (ECBM). The causal model is illustrated in Eq. (1).

$$\mathrm{TC(kWh)_I} = (\mathrm{Bulreg}) + (\mathrm{ECon}) + (\mathrm{Socasp}) + (\mathrm{Comf}) + (\mathrm{Edu}) + (\mathrm{Socmar}) + (\mathrm{Direct}) \tag{1}$$

where TC (kWh) = total energy consumption; Bulreg = building regulation; Socasp = social aspiration; ECon = environmental concern; Comf = comfort; Edu = education; Socmar = social marketing; and Direct = activities and device.

After the above process was completed, holdout samples were next to be analysed. The first process was to determine holdout sample energy consumption level (observed energy consumption). Next was to predict consumption levels through the ECBM model developed early. Third, the holdout sample was segregated according to their pattern based on the normal energy consumption determined early. Finally, potential energy savings were calculated based on the predictions of energy consumption and normal energy consumption. The overall methodology is depicted in Table 2.

4. Results and discussion

Twenty-five percent of the respondents were selected as the holdout sample for next analysis. In the first process, 1009 respondents were analysed. Respondents consist of 491 male and 518 female from four selected universities. Four selected HEIs were involve in this research, namely Universiti Teknologi Malaysia, Universiti Malaya (UM), Universiti Sains Malaysia (USM), and Universiti Putra Malaysia (UPM). Based on the observe energy consumption calculations, the mean energy usage for student daily is 6.1 kWh.

Based on the SDE calculation, the results indicates that the $\mathrm{SDE_x}$ is 29 and $\mathrm{SDE_y}$ is 9, or the normal energy consumption was at (29, 9). Such numbers will be the first indication of the energy consumption pattern segregation on the graph. The formula for calculating the SDE is illustrated in Eq. (2).

Table 1
Factors and unit of measurement.

Factors	Unit of measurement
Building Regulation (BulReg)	Continuous rating scale
Environmental Concern (ECon)	Continuous rating scale
Social Aspiration (SocAsp)	Continuous rating scale
Comfort (Comf)	Continuous rating scale
Education (Edu)	Continuous rating scale
Social Marketing (SocMAr)	Continuous rating scale
Activities (Act)	kWh
Device (Dev)	kWh

$$SDE_x = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \overline{X}\right)^2}{n}} \quad SDE_y = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \overline{Y}\right)^2}{n}} \tag{2}$$

where x_i ($x = kWh$) and y_i ($y = duration/hours$) are the coordinated for feature I, $\{\bar{x},\ \bar{y}\}$ represent the mean centre for the features, and n is equal to the total number of features. Through the SDE calculation, segregation of the pattern can be made. Four types of pattern were determined, namely “High” energy user (> 29, > 9) (15% respondent), “Low” energy user (< 29, < 9) (17% respondents), “Conserve” energy user (> 29, < 9) (68% respondents) and “Medium” energy user (< 29, > 9) (0% respondents). However, “Medium” energy users will not be analysed because of the lower number of observation.

4.1. ECBM

In general, all the factors involved in the ECBM were expected to be significant. Because all factors were based on the “energy culture” framework. “Energy culture” framework suggests that the three core aspect (material, cognitive norm and energy practice) must be processed together [26]. The next concern of the model is the direction of its coefficient. Direct factors (device and activities) were expected to have positive direction (+). The reason is that these factors were measured using kWh unit, and hence, increase of one unit of each factor would increase the total consumption. On the other hand, indirect factors (building regulation, environmental concern, social aspiration, comfort, education and social marketing) were expected to have negative direction (−). The higher the index cited by the respondent, the higher the acceptability and understanding of the factors of their self. Hence, increase of one unit of the factors will decrease the total consumption.

The analysis of the ECBM shows that the model has a variation of 99% ($r = 0.996$) with the Anova test indicating that the model is significant. The model has the highest variation compared to the previous studies that interpret Dev and Act factors together [26–28]. The results also show that the factor in the model has no multi collinearity problem (mean VIF = 1.8 < 10). In the model, building regulation ($\beta = -.006$, $p < .05^*$), environmental concern ($\beta = .011$, $p < .05^*$), education ($\beta = -.005$, $p < .05^*$), social marketing ($\beta = .004$, $p < .10^{**}$), and direct ($\beta = 4.858$, $p < .05^*$) were found significant to energy consumption. However, social aspiration and comfort were not significant to the model. Hence, the two factors were eliminated from the model. The final model of ECBM illustrated in Eq. (3).

$$\mathrm{TC(kWh)} = -1.32 - 0.006(\mathrm{BulReg}) + 0.011(\mathrm{ECon}) - 0.005(\mathrm{Edu}) + 0.004(\mathrm{SMar}) + 4.858(\mathrm{Direct}) \tag{3}$$

Overall, building regulations and educational factors was found to be aligned and fulfil the model's expectation. Building regulations are rarely discussed in multiple regression analysis. Although there is no comparison of the result, the results nevertheless show that building regulation is fit with the model requirement. Building regulation factor is significant ($p < 0.05$) and has an expected direction (−.006). The result indicates that increase of one unit of acceptability in building regulation will decrease the amount of energy consumption. Similar to the education factor, it was found significant and in an expected direction. In also indicates that an increase of one unit of acceptability in education will decrease the amount of energy consumption among students. Previous research also found that education factor is significant in their analysis and had the same direction as the results [27,28].

Table 2
Research methods and tools.

Stage	Method	Variables	Tools	Output
One	a. Quantitative (Questionnaire - 4 selected universities - 1400 students)	Energy Culture Framework: a. *Material*: Device, and Building Regulation. b. *Energy Practice*: Activities, and Social marketing	a. Descriptive statistic. b. Standard deviation ellipse (SDE). c. Multiple regression analysis (MRA)	a. Observed energy consumption b. Energy consumption pattern c. Normal energy consumption d. Factors influence
Two		c. *Cognitive norm*: Social aspiration, Environmental concern, Comfort, and Education.	a. MRA b. Multinomial Logistic regression (MNL) c. Descriptive statistic.	a. Energy consumption behaviour model (ECBM) b. Energy consumption behaviour pattern model (ECBPM)
	a. Holdout sample		a. ECBM b. ECBPM c. Different on observed, predicted, and normal energy consumption.	c. Potential energy saving

Compared to environmental concern and social marketing, these factors are also significant in the model; however, it shows an unexpected direction of the model. Based on previous studies, it has been reported that the environmental concern factor is not significant in their model [26,27]. However, the coefficient direction based on these two projects is the same. As discussed earlier, environmental concern factor was expected to be significant and in negative direction. This means that increase of one unit acceptability of the factors will decrease the amount of energy consumption. However, the result shows otherwise.

The direct factor was expected to be significant and positive ($\beta = 4.858$, $p < 0.05$). The results are aligned with several previous research activities that combined the activities and device factors. Previous study reported that the combination of the factors is significant with their models with $p < 0.05$ [26–28]. Furthermore, the coefficient of direct factor has the same directions [26–28]. Hence, the factor indicates that an increase of one unit in the direct factor will increase the amount of energy consumption. Also social aspiration and comfort are not significant in the model. Hence, the two factors were eliminated from the model.

Social aspiration and its link with energy consumption have been taken seriously by researcher. Social aspiration here includes beliefs, values, and habits. Again, it has been demonstrated that this factor does not link directly with energy consumption. The results show the same findings as previous research [26–31]. Therefore, based on both previous studies and the ECBM findings, social aspiration has been dropped from the model because it has been proven from both perspectives that it is not significant to energy consumption.

Comfort factors were also dropped from the ECBM. This factor was found to be insignificant with the model. Furthermore, looking back to previous studies, comfort factors were less highlighted by researchers in energy consumption behaviour studies. Previous study found that it is significant with energy consumption [26]. However, the researchers also stated that the scale has measurement errors and suggested better measurements in the future; again they posited that this factor is related to energy use [29]. It was agreed that comfort is a demand factor and one of the drive change in behaviour [18,26,32–35]. Therefore, comfort factor is unexplained and has to be dropped from the model. Future work must consider this factor using other methods with both the behaviour patterns and present amount of energy individual required [36].

4.2. Potential energy saving

In this section, discussion will go through the analysis for potential energy saving among Malaysian HEIs students. The analysis used the ECBM for determining student energy consumption levels, and Normal energy consumption (29, 9) was used to segregate the energy consumption pattern from the observe consumption.

Holdout sample consists of 349 respondents. The amount predicted energy consumption was in range of -1.3 kWh minimum and 32 kWh maximum. The mean of the predicted energy consumption is 2.5 kWh. Compared to observed energy consumption, the mean (5.9 kWh) is more than double from the predicted energy consumption. This indicates that ECBM has revealed the amount of energy that may be used by respondents based on energy consumption behaviour factors.

Based on the segregation analysis, 27 of the respondent were determined as “High” energy user pattern (8%), 164 respondents are the “Low” energy user (47%), and 158 respondents are “Conserve” energy user (45%). Therefore, only the “High” energy user pattern was selected for determining potential energy savings.

Two types of calculation were made for determining the potential energy saving. Firstly, the difference between “High” energy individual observed energy consumption (a) and the predicted energy consumption (b), calculated from Eq. (3). Secondly, potential energy saving is calculated through the difference between “High” energy individual observed energy consumption and the normal energy consumption (x) determined earlier in objective one through SDE calculation (9 kWh). This calculation is illustrated in Eq. (4) below:

$$\begin{aligned}&(\mathrm{A})\ \ (a - b) = \text{Potential energy saving 1 } (\Delta ab)\\&(\mathrm{B})\ \ (a - x) = \text{Potential energy saving 2 } (\Delta ax)\end{aligned} \qquad (4)$$

The potential energy saving from observed consumption (a) is 65.34 kWh minus predicted consumption (b) is 32.01 kWh from Eq. (4) (A), the different is 33.33 kWh. Compared to second calculation, the observe consumption (a) which is 65.34 kWh minus normal consumption (x) (8.82 kWh), the potential energy saving from Eq. (4) (B) is 56.52 kWh, 23.19 kWh higher from observed minus predicted energy consumption.

5. Conclusions

The result has shown that there is huge potential energy saving with over 55 kWh reduction can be gathered through the methodology proposed. Using the concept of “energy culture” framework as a basis, the factors were analysed using a centrographic approach for determining the normal energy consumption levels and segregated the energy consumption pattern. The same data were used to develop the energy consumption behaviour model. The model had a capability to predict the energy consumption behaviour for each respondent. Finally, the model was tested using the holdout sample and the potential energy saving can be determined.

The centrographic approach has the ability to determine the normal energy consumption from the observe energy consumption. Four types of energy consumption pattern can be segregated namely "High", "Medium", "Low" and "Conserve" energy user. However, "Medium" energy users were eliminated from the analysis because of lower number of the respondent. This shows that there are three primary types of energy consumption patterns among Malaysian HEIs students.

In conclusion, this paper has proposed a methodology for assessing energy consumption behaviour among Malaysian HEIs student. The analysis has potential to be expanded by analysing the characteristic of the energy consumption pattern for better understanding of each pattern. Furthermore, a prediction model of the energy consumption behaviour pattern may be developed in the future using logistic regression. Therefore, a solid mathematical explanation can be found in the pattern.

The methodology is easy to understand and apply among Malaysian HEIs students accommodation. It has the ability to determine energy consumption levels and current energy consumption patterns. This information is important especially for facilities managers for managing the energy of the buildings. It also helps in determining the right type of conservation program.

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